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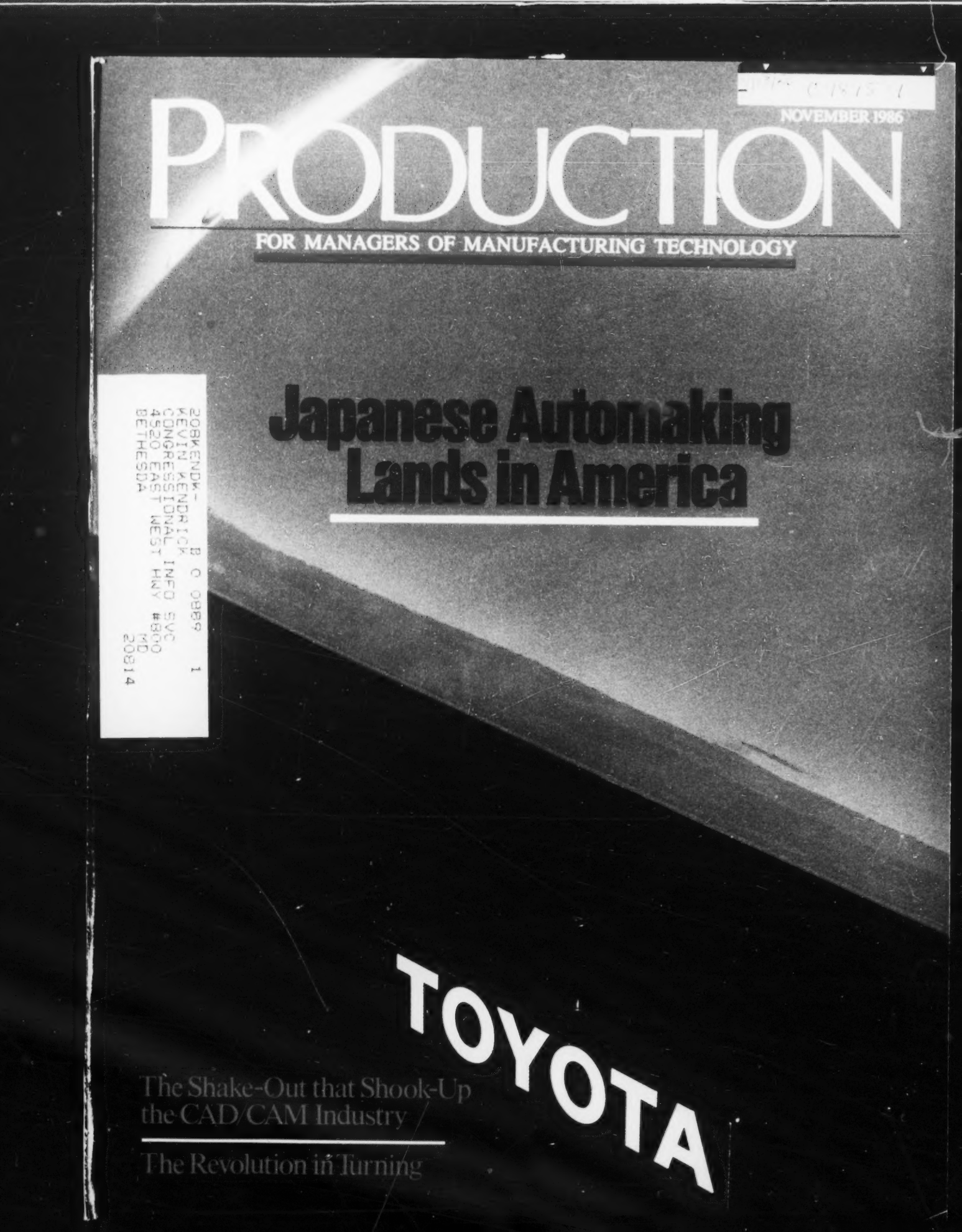
Japanese Automaking Lands in America



The Shake-Out that Shook-Up the CAD/CAM Industry

The Revolution in Turning

PRODUCTION

NOVEMBER 1986 VOL. 98 NO. 5

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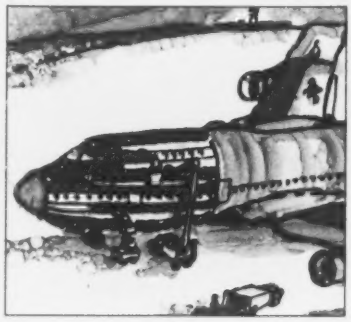

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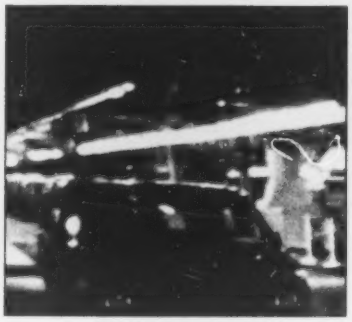

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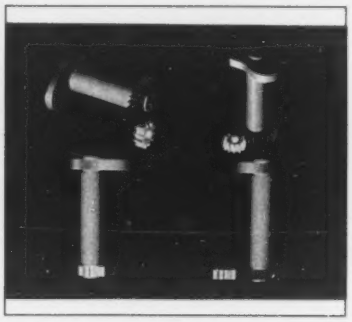

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JAPANESE AUTOMAKING LANDS IN AMERICA

42 *American auto manufacturers are scurrying to match the high technology manufacturing operations, the productivity gains, and the quality assurance that have been the hallmarks of Japanese car plants that have been "transplanted" in the U.S.*

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Cover photo by Robert Penneys. Truck courtesy of Central City Toyota, Phila. PA.

U.S. Automakers See World-Class Quality by 1990

QUESTION: **FOR EACH OF THE FOLLOWING PERFORMANCE MEASURES, INDICATE YOUR ASSESSMENT OF WORLD CLASS PERFORMANCE, AS WELL AS YOUR COMPANY'S CURRENT PERFORMANCE.**

	VEHICLE MANUFACTURERS	
WORLD CLASS PERFORMANCE MEASURES	WORLD CLASS PERFORMANCE	CURRENT PERFORMANCE
Percent of processes which are statistically capable of first-time quality production at designed rate	90%	50%
Total lead-time from engineering concept through start of production for new products	36 mo.	60 mo.
Percent of products which meet cost objectives after first year of production	80%	50%
New equipment uptime during first year of production	90%	60%
Total production lead-time from first operation through "Ready to Ship"	2 days	3 days
Average days to process an engineering change from request through production implementation	30 days	100 days
Average number of engineering changes generated internally for a product in first year of production	80	600
Annual research and development cost as a percent of sales	5%	3%
Raw material yield in first year of production	80%	60%
Fixed asset turnover, which is defined as annual cost of sales divided by fixed assets employed (plant and equipment only)	4	3
Sales per square foot of plant (including both productive and storage areas for raw materials, WIP and finished)	$1,000	$1,120
Average number of levels in the manufacturing bill-of-material for a plant's products	3	5

A substantial need for manufacturing improvement exists if U.S. auto building is to become "world class." That conclusion can be drawn from a mini-Delphi Survey conducted by the Detroit office of Arthur Andersen & Co.

Respondents to the survey included 14 vehicle manufacturers, 76 automotive parts suppliers and 28 other related manufacturing companies. Most respondents percieve a significant gap between their current performance and world-class performance needed to be competitive in the world marketplace.

Most of the respondents also said that they could accomplish the improvements by 1990. The table ranks, in order of importance, the problems and also indicates a measure of the magnitude of improvement needed. The consensus of the survey indicated, for example, that a world-class vehicle manufacturer would get new processes and equipment up and producing specified quality and output 90 pct of the time. Today's average is 50 pct. Similarly, a world-class manufacturer could go from engineering concept to product production in 36 months. It now takes 60 months.

The fact that many respondents cited 1990 as the time when they will have closed the gap is, to one observer, "At the very least, optimistic."

GM, Japanese Firms Form Joint Ventures

When General Motors positions itself to face the competition, the results are frequently—unique, with the latest such strategy resulting in joint venture agreements with three Japanese firms: Suzuki Motor Company, Akebono Brake Industry Company and NHK Spring Company.

The Suzuki venture with General Motors of Canada includes the building of a new 1.6 million-sq.-ft. facility in Ingersoll, Ontario that will have an annual production capacity of 200,000 cars and light utility vehicles. Next generation Chevrolet Sprint, Pontiac Firefly (sold only in Canada), the Suzuki Forsa and a utility vehicle similar to the Suzuki Samaurai 4WD unit will be produced there when the plant starts up in 1989.

In the United States, General Motors and Akebono Brake Industry Co. have selected Elizabethtown, Ky., as the plant site for this joint venture. To be known as American Brake Industry Corp., the 50/50 venture is expected to produce 1 million brake shoes and 30,000 disc brakes monthly when production begins in early 1988.

In Japan, the Inland Division of General Motors and NHK Spring Company are joining expertise in FRP spring R&D by forming the NHK Inland Corporation.

The new venture, which will be majority controlled by its Japanese parent, will make use of an existing NHK Spring Co. facility near Tokyo to produce the FRP units.

Robot Shipments Down 13 Percent

U.S. manufacturers shipped nearly 5,800 robots in 1985, down 13 pct from the approximately 6,500 in 1984, according to the Census Bureau.

The robots shipped were valued at $317 million. Robot accessories, subassemblies, and components and parts shipments totaled another $70 million, up from $56 million in 1984.

The largest category of robots shipped in 1985, accounting for 19 pct, were those used for welding, soldering, brazing, and/or cutting. They were valued at $97 million. Next were robots used to spray, paint, glue and/or seal, valued at $83.4 million.

The report gives information on the anticipated end-use or function of robots as well as data on robot accessories, sub-assemblies, and components and parts. It contains substantial revisions to data released in the 1984 report, which was the first year this information was collected. Revisions were caused by late reporting, corrections to exclude some imported robots, and corrections to exclude some reporting of the total value of systems that include robots rather than just the value of the robots themselves.

Technical Ceramics Market Projections—1985-94
North American (Million 1984 Dollars)

EXISTING APPLICATIONS

	1985	1994	1985-1994 Average Annual Real Growth	Leading Products	Leading Materials
Electronics	$1,375	$2,500	7- 8%	IC Packages, Capacitors	Alumina, Mullite, BeO-Sic, Silicon Nitride
Catalysts	100	140	3- 4	Particulate Traps	Cordierite
Military/Aerospace	35	165	20	Radomes, Armor	Zirconia, TiB_2, SiC
Wear Products	35	50	4- 5	Nozzles, Cyclones	Silicon Carbide, Alumina
Pump and Valve Components	16	30	7	Valve/Pump Trim	Silicon Carbide
Instrumentation	15	30	7	Industrial Sensors	Zirconia
Tools and Dies	32	75	10	Rotary Cutting Tools/Coatings	Sialon, Alumina, Silicon Nitride
Process Equipment	15	75	15-20	Filtration Media	Alumina Silicate, Alumina
Dental/Medical	5	25	15-20	Dental Restorations	Alumina
Sub-Total	$1,638	$3,090	7- 8%		

Base Data: Technomic Consultants

High Performance Ceramics to Grow From $1.6 To $3.1 Billion by 1994

The age of ceramics in high performance applications is expected to grow from $1.6 billion to $3.1 in 1994, according to the Norton Company and a study conducted by Technomic Consultants, Inc.

In a recent press conference held by Norton at its High Performance Ceramics headquarters in Northboro, Mass., company executives pointed to new and existing opportunities for growth in the industry.

Richard A. Alliegro, vice president for the company's High Performance Ceramics Division noted, that studies show that electronics is the dominant segment of the market representing more than 80 percent now and about 80 percent in 1994. Military and aerospace applications amount to about $35 million currently and could grow 20 percent a year over the decade.

Said Mr. Alliegro, "In addition to the existing opportunities, new ones will evolve between 1989 and 1994 including ceramics for heat engines."

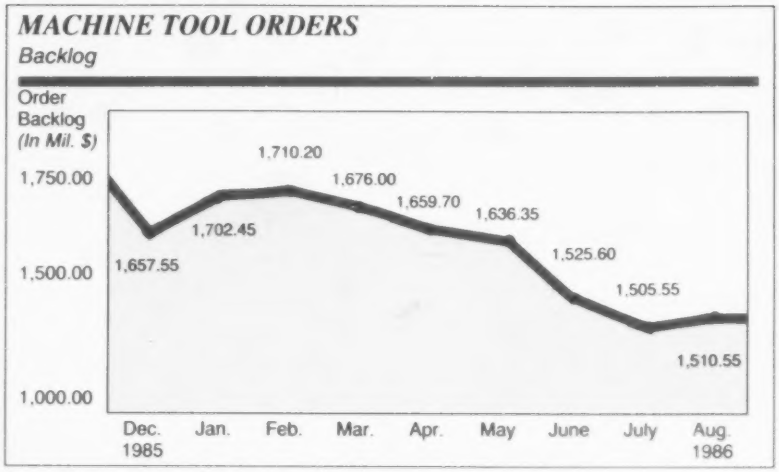
He estimated "These users of ceramics could begin to commercialize in 1990 growing to $75 to $100 million with a real possibility of $500 million."

Total market figures could surpass $5 billion perhaps pushing $10-$12 billion by the end of the decade, he said.

"Newer applications such as heat sinks for electronic packages, heat exchange tubes for high temperature furnaces are extending their utility however in the structural area we've barely scratched the surface," he said.

"Take for example, silicon nitride cutting tools as a replacement for tungsten carbide in machining cast iron. In one particular test involving silicon nitride tools mounted on a high speed spindle operating at 8000 rpm driven by a 200 horsepower motor, an engine cylinder was bored out in one second, four cylinders in four seconds. The normal rate for this operation for four cylinders with carbide was 44 seconds. This is a tremendous reduction in time, indicating a real revolution in productivity brought about by advanced ceramics," he noted.

"Ceramic bearings will likewise revolutionize many traditional applications where steel bearings are currently used. Miniature precision ball bearings made of ceramics are already finding application in environments where lubrication is a problem, for instance, space instrumentation, and certain products like CAT scanners where motors must operate in a vacuum. Main shaft bearings for gas turbines is a natural, the challenge here is one of reliable, predictable, and performance that can only be brought about by extraordinary care in manufacture. Non-destructive evaluation, NDE, must also be emphasized to ensure product quality," he said.



Machine Tool Orders Off $9.3 Million in August

Machine tool orders continued to decline in August from their July total of $170 million, according to the National Machine Tool Builder's Association.

New orders for August fell to $154.25 million, a drop of $9.3 million from the month earlier total.

Orders for metal cutting machinery fell to $114.75 million, a drop of 10.9 percent from the $120.80 million posted in July. Metal forming equipment orders fell from $41.20 million in July to $39.50 million in August, a 4.1 percent drop.

Comparing August 1986 with August 1985, metal cutting machine tool orders fell by 12.3 percent while orders for metal forming equipment fell by 26.4 percent, resulting in a combined drop of 16.4 percent. Year-to-date orders for metal cutting machine tools were down 11.1 percent compared to the same period in 1985, while orders for metal forming equipment dropped 15 percent. Combined orders through August 1986 totalled $1,540.60 million, a drop of 12.2 percent from the $1,754.00 million for the same period in 1985.

August shipments of metal cutting machine tools fell to $108.30 million from $149.10 million in July, a drop of 27.4 percent for the month. This figure represents a fall of 24.3 percent compared to shipments in August of last year. Metal forming shipments remain unchanged for the month, holding at $40.95 million. This represents 43.8 percent drop when compared to August of 1985. Total shipments fell 21.5 percent for the month dropping to $149.25 million. Compared to August of 1985 shipments were down 30.9 percent.

Machine tool order backlogs for August stood at $1,510.55 million up from the $1,505.55 million in July.

Okuma Ups Prices 15 Percent

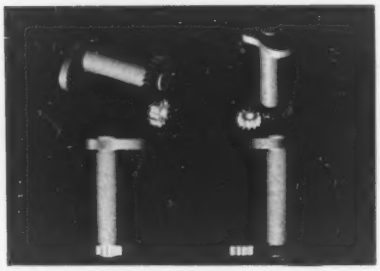
As evidence of the general decline in sales of Japanese machine tools worldwide, Okuma Machinery, Inc. has increased its prices on all of its products with the exception of its newest introductions.

The company's CNC lathes, machining centers and cylindrical grinders will be increased 15 percent according to Tadeo Okuma, the company's chairman and John D. Hendrick, senior vice president of the company.

The increase is the second price hike since March 31st of this year and according to Mr. Okuma and Mr. Hendrick it was prompted by "the change in the value of the dollar versus the yen."

Both Mr. Okuma and Mr. Hendrick noted "The yen has substantially increased the cost to provide Okuma products and services in the U.S. Now a price increase is not only warranted, it's needed."

The Shake-Out that Shook-



New companies, emerging with an unprecedented vigor since 1984, have been noted for introduction of radical implementation of technology.

IN THE REALM OF COMPUTER INTEgrated manufacturing (CIM), the CAD/CAM industry's most alluring buzzwords are graphics and solid modeling. Now that industry has effectively resolved the problem of cost to computational capacity, graphic engineering workstations with sophisticated applications software such as solid modeling, and shop floor devices—also equipped with graphic capability—are being strategically implemented to revolutionize manufacturing.

The dramatic shake-out experienced by the CAD/CAM industry during the 1983 time frame has forced surviving companies to develop new and improved versions of computer hardware and software. In addition, new companies, emerging with an unprecedented vigor since 1984, have been noted for introduction of radical implementations of the technology.

For example, a typical microcomputer today offers more than 20-times the processing power, 20-times the main memory and 500-times the disk storage—at less cost—as microcomputers of the late 1970's.

Further, new software capabilities—including solid modeling, Finite Element Analysis (FEA), mechanisms analysis, more efficient operating systems (O/S) and networking—coupled with steadily improving price/performance ratios have contributed to the increased availability and use of computer-based tools in the manufacturing environment.

In short, competition is keen. As a result, however, never before has the industry offered so expansive a field of functional, cost-effective and easy-to-use tools capable of full integration from conceptual design through production.

According to a survey of CAD/CAM-CAE systems and vendors published by Daratech, Inc., Cambridge, Mass., worldwide usage of CAD/CAM-CAE—driven principally by personal computer-based units costing as little as $5000—is growing by an astounding 10,000 units per month.

Where is this equipment going? Largely to the shop floor.

Implementation of graphics on the shop floor has almost unlimited possibilities—as part of a machine tool control showing what is going on or previewing the next job, as an adjunct to programmable or process controllers showing the status of work cells or a whole line, as a read-only operator assist for drawings or process plans, or as a real-time assembly line aid to provide assembly instructions and drawings without any paperwork.

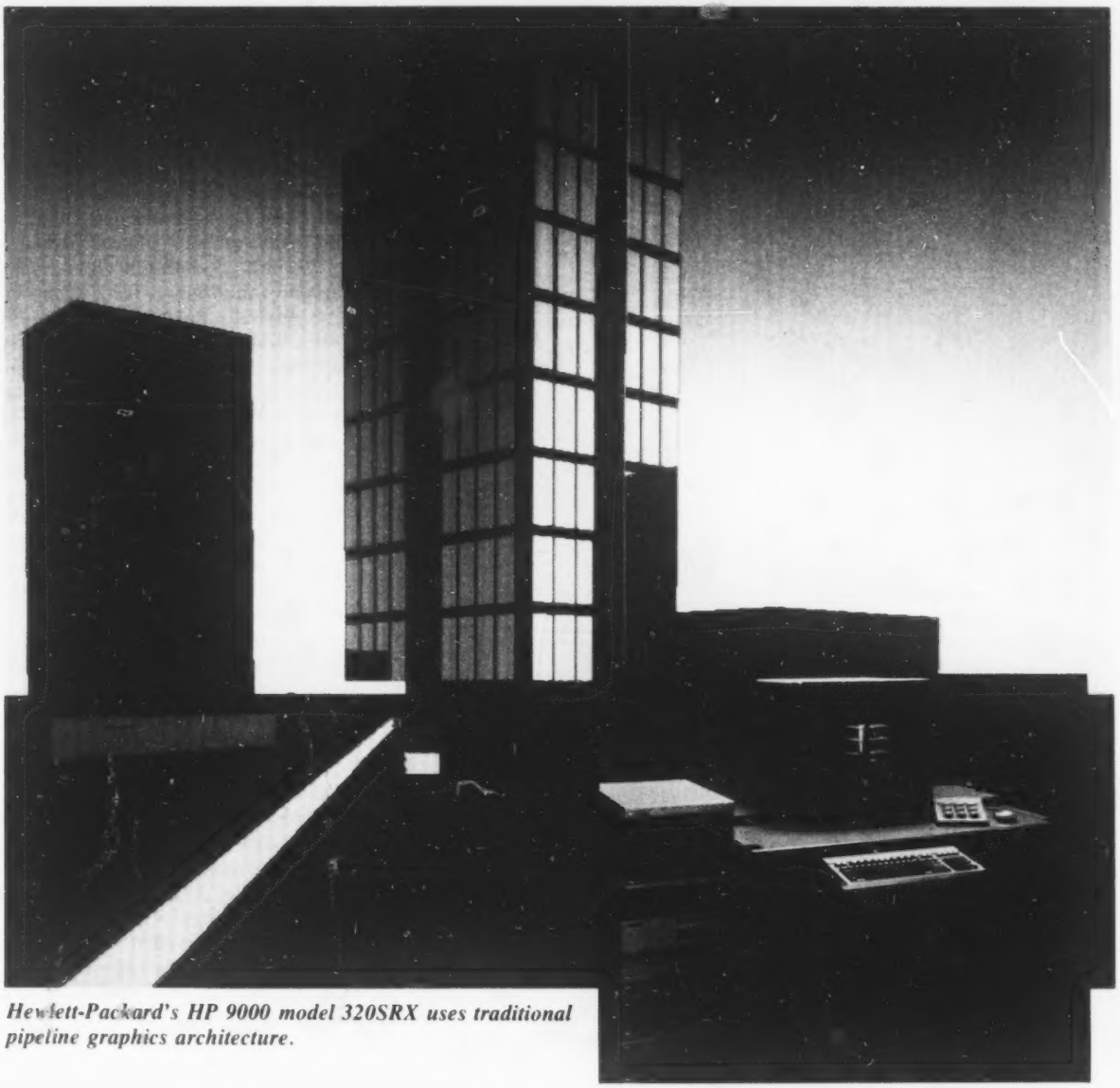
A study conducted by the Yankee Group, Boston, Mass., concluded that graphics on the shop floor have the potential to change the rules in manufacturing by allowing the operator to control the manufacturing process. With shop floor graphics, automation can be a support for line workers who require information on processes and equipment quickly, in an easily understood format and completely enough to provide a basis for decision and action.

In the factory environment, shop floor graphics is in its infancy compared to its wider use in the engineering/design world. However, in the next five years it is forecast that the growth rate for shop floor graphics will be faster than that of engineering/design graphics. The narrowly defined factory floor graphics market is estimated to be $188 million in 1985 and is expected to grow at 30-35 percent per year for the next few years.

Considering that estimates for the growth of factory automation, although varied, reach $90 billion by 1990, it can be safely assumed that the computer graphics segment of the CIM market will have a dramatic impact on the future of manufacturing. Although it is generally conceded that total lights-out manufacturing will not be a common occurrence for at least five more years, it is evident that more and more companies will be quickly approaching that goal.

By Sandra Lee Brooks
Mid-West Editor

Up the CAD/CAM Industry



Hewlett-Packard's HP 9000 model 320SRX uses traditional pipeline graphics architecture.

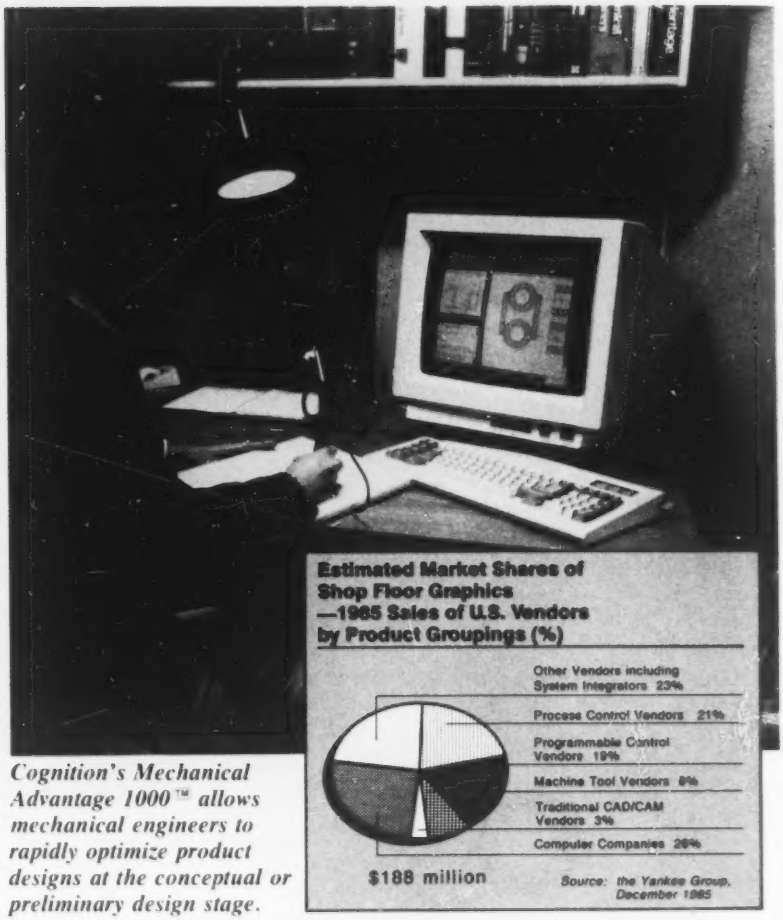
How, then, can computer-based graphic tools—broadly defined as CAD/CAM—best be utilized to take full advantage of CIM concepts to achieve a competitive edge in manufacturing?

Concept Engineering

The success or failure of a product is often determined by the quality and timeliness of engineering decisions made at the conceptual design stage of product development. It is *the* most important phase in determining ultimate product cost, performance and reliability.

Therefore, engineers responsible for conceptual design are under tremendous pressure to quickly optimize a design while observing a multitude of constraints. In an effort to minimize lead-times, tooling, materials and production costs, however, the integrity of the overall product concept may be compromised.

Up to this point, few computerized tools have been available for use in


Estimated Market Shares of
Shop Floor Graphics
—1985 Sales of U.S. Vendors
by Product Groupings (%)
Other Vendors including System Integrators 23%
Process Control Vendors 21%
Programmable Control Vendors 19%
Machine Tool Vendors 8%
Traditional CAD/CAM Vendors 3%
Computer Companies 26%
$188 million
Source: the Yankee Group, December 1985

Cognition's Mechanical Advantage 1000™ allows mechanical engineers to rapidly optimize product designs at the conceptual or preliminary design stage.

conceptual design, most being limited by very specific solutions, non-integrated architecture, difficulty of use and excessive cost.

A new company, sprung from the debris of the early 1980's shake-out, has brought to market a software product which incorporates advanced computer-assisted technologies and artificial intelligence techniques to allow for the optimization of conceptual product designs easily and rapidly.

Founded in February 1985 by Philippe Villers (Villers founded Computervision in 1969), Cognition Inc., Billerica, Mass., has created the first fully integrated mechanical computer-aided engineering (MCAE) system. Known as Mechanical Advantage 1000 (MA 1000), the system deals with the conceptual or preliminary design stages during which engineers develop, examine, analyze and refine product design alternatives.

MA 1000 generates an integrated engineering model that stores both the geometry of a design concept and the underlying engineering principles. An intelligent electronic notebook stores the history and engineering intent of a design. Resident expert systems extend the engineer's skills allowing a user to easily explore design and manufacturing alternatives. An optimal design can then be passed to a CAD/CAM system, via IGES (Initial Graphics Exchange Specification) and specialized translators, for the creation of detailed engineering drawings. The integrated engineering model, containing both geometry and analytical information, can then be used to test a design concept before building a prototype.

Each MA 1000 system includes a Cognition Application Engine Plus (CAE+), based on Digital Equipment Corp.'s MicroVAX II, connected by an ethernet local area network (LAN) to up to five personal workstations. Based on augmented IBM PC/ATs with high-resolution color monitors, the CAE+ uses ULTRIX-32M, DEC's UNIX operating system; personal workstations are CGA-compatible for full use of IBM graphics programs. These use the MS-DOS operating system, allowing access to other software packages.

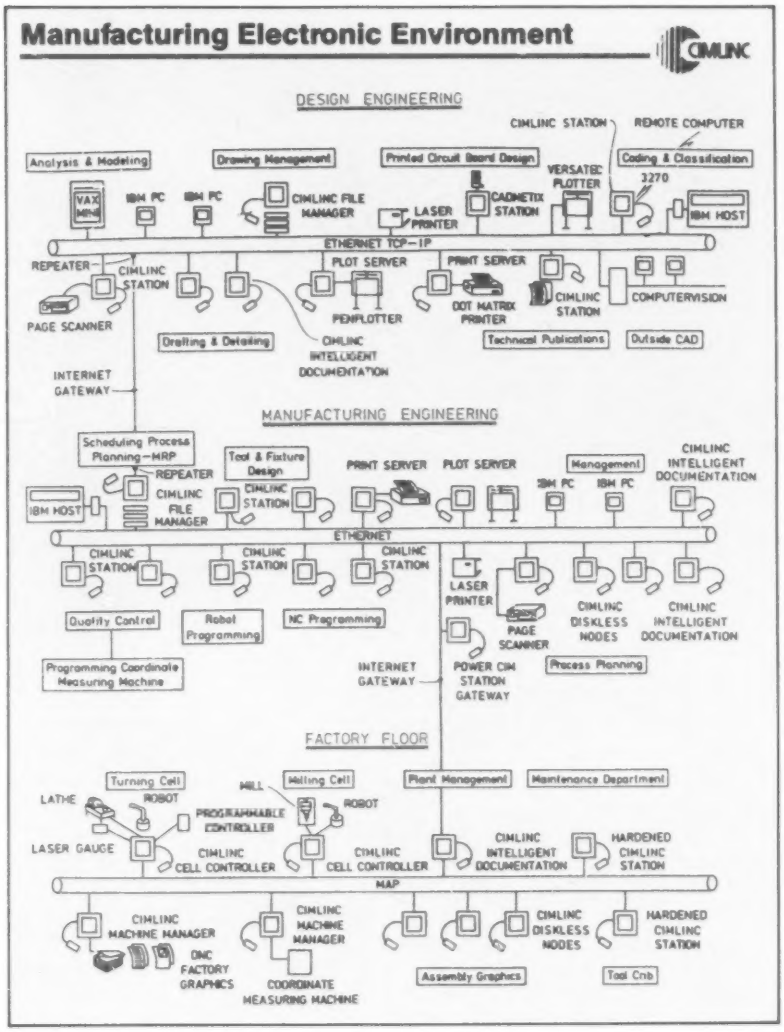
Looming on the horizon is yet another start-up, Aries Technology Inc., Lowell, Mass., also positioned to serve the needs of the conceptual design engineer. Founded in 1984 by Gerald Christopher (formerly DAVOX Corp.), Richard Miller (formerly Applicon, Inc.), Dr. Jack Horgan (formerly Applicon), Arthur McCray (formerly CAD/CAM Consulting Group), and Jerry Sabath (formerly Applicon), Aries Technology plans to unveil its first products during the AUTOFACT Exposition & Conference, November 11-14, Detroit, Mich.

By automating concept engineering, design geometry will be more easily created, verified and modified prior to sending it on to drafting. This, in itself, will increase the quantity and enrich the quality of design alternatives engineers can consider within time and budget constraints. In fact, concept engineering systems can be expected to shorten the total concept-through-manufacture cycle by up to 30 percent, according to Aries Technology.

Further, the number of prototypes necessary for verification will be significantly reduced, or even eliminated. It is conceivable that a data base initiated in design will eventually be used to directly program manufacturing processes.

CAD/CAM

Time was that computer-aided design was simply 2-D tube-generated 'pictures', computer-aided manufacturing an NC tape-prep methodology and advanced software techniques such as solid modeling, finite element analysis and 3-D anything resident only in experimental laboratories in a handful of



Cimlinc has focused its hardware and software development to integrate islands of automation throughout the factory environment.

the world's leading universities and R&D institutions.

As recently as 1980-82, the industry was still seeking solutions to "closing the gap" between CAD and CAM, pursuing a reliable method of transferring data between computer files. Since then, the development of standards and the astounding sophistication of computer hardware and software systems has literally melded that which "never the twin shall meet" into a massive conglomeration of applications software, often built upon successive "CAD/CAM" sessions with data being easily transferred from file to file until, finally, the data is downloaded to a cell controller which initiates a manufacturing operation.

Vendors once defined as CAD or CAM now offer expansive libraries of applications software and improved hardware and software interface capabilities which encourage the use of competitor's or third-party programs. As a result, users can easily build a 'custom' CAD/CAM system selecting those hardware and software products which provide only those capabilities necessary to maximize operations unique to an organization from, virtually, off-the-shelf products. The 'whiz-bang' days of the infant computer industry have been supplanted by modular functionality.

For example, Autodesk, Inc., Sausalito, Calif., produces a computer-aided drafting and design program known as AutoCAD. The micro-based CAD software allows 2-D drafting and 3-D visualization enhanced by such features as a variety of editing commands, pan and zoom operations, a general UNDO capability, support for Lotus/Intel expanded memory or IBM PC/AT extended memory which yields increased processing speed, color and line type differentiated by individual entities rather than complete layers, a time accounting facility, enhanced construction facilities including line tangent to two circles, dual-standard dimensioning in feet/inches and metric units and commands for creating ellipses, doughnuts and polygons.

An interactive programming language built into the software, AutoLISP, allows direct access to the drawing entity data base making it easier to customize AutoCAD for specific applications.

The software supports IGES 3.0, allowing two-way exchange of drawings between AutoCAD and other CAD systems supporting IGES. In addition, conformance to the IGES standard and the power of AutoLISP resident in the AutoCAD software has encouraged independent developers to produce a wealth of specialist add-on programs for AutoCAD.

AutoCAD has been designed for use with 16-bit PCDOS/MSDOS computers and the high-performance 32-bit workstation environment of the UNIX-based IBM RTPC, Sun 2 or Sun 3. The retail price for all these versions is the same, $2750.

(No wonder that Autodesk enjoys recognition as the producer of the world's most widely used computer-aided drafting and design program. AutoCAD holds 44+ percent of the PC-based CAD market.)

Applicon, Ann Arbor, Mich., (a Schlumberger company), has been best known for its leadership in the compu-

Swanson Analysis Systems has developed a computer program (ANSYS) which can construct models of structures or machine components, apply operating loads and study physical responses such as stress or temperature distribution–all without having to build the object or destroy it in testing.

ter assisted NC programming field. The company holds over 60 percent of the market share.

Recently Applicon integrated its Bravo3 CAE/CAD/CAM software with its NC programming products. The result is manufacturing capabilities expanded to include a comprehensive Design and Documentation package, along with the most widely used NC programming capability in the industry, COMPACT II.

Therefore, the system may be implemented at any stage of the product cycle from conceptual design through manufacturing. The integration of Bravo3 allows users to interactively create, modify, test or process design information in 3-D, minimizing the need for prototypes.

The Bravo3 system is resident on Applicon's high-performance workstation which utilizes the Motorola 68020 microprocessor.

Cimlinc Inc., Elk Grove Village, Ill., has focused its hardware and software development to integrate islands of automation throughout the factory environment. It's CIM system, called Power CIM, includes a range of software applications and a modular workstation environment derived from the Motorola 32-bit 68020 microprocessor.

Cimlinc's CIM CAD software, a graphics-based design, drafting and detailing package passes 2-D geometry to CIM CAM (a machine tool simulation program) or 3-D wire frame models to CIM SIRF. Also available is a 3-D modeling tool and a parametric design program which allows for optimization of conceptual design.

Cimlinc provides ethernet and MAP (Manufacturing Automation Protocol) communications, as well as links to IBM's SNA 3270 networks.

Computervision, Bedford, Mass., has modifed and migrated its CAD/CAM software to the personal computer environment.

The Personal Designer system provides production capability of design, drafting and analysis functions on the IBM PC/XT or AT.

MicroCADDS Geometric Construction and detailing and MicroCADDS Surfaces, the principle software for the Personal Designer system, are based on CADDS—Computervision's well known 15-year old base software product. The system can produce 2-D and 3-D engineering models, detail drawings, library parts, even shaded drawings.

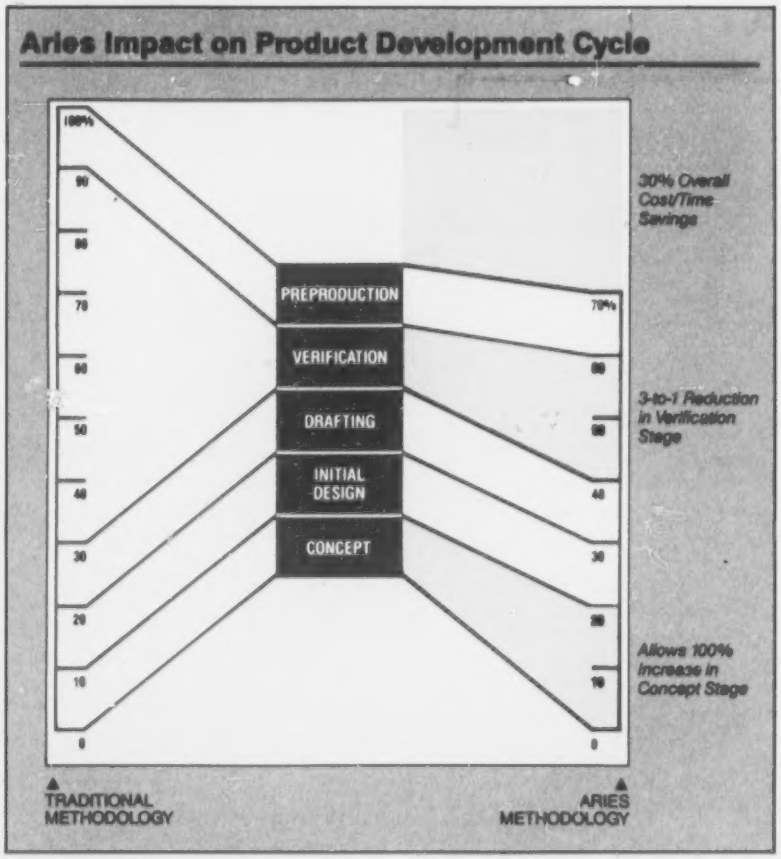
For increased functionality, the Personal Designer system can be interfaced to IBM, Digital Equipment Corp. VAX and Computervision V-X or CDS 4000 series computers. Further, the system supports selected third-party mechanical design software.

Intergraph Corporation, Huntsville, Ala., recently introduced a next generation series of graphics workstations which contain the powerful 32-bit CLIPPER processor from Fairchild Semiconductor Corporation. This microprocessor, maximized for scientific and professional computing applications in the UNIX environment, operates at a 30 nanosecond instruction cycle time yielding five times the performance of a DEC VAX-11/780.

Intergraph's offering of application software includes CAD, CAM, finite element modeling, parametric design, mechanism modeling, sculptured surface and flap pattern nesting programs. NC programming software includes packages for Design/Toolpath Integrity, Machine and Tool Libraries, Toolpath Verification, Milling, Turning, Sheet Metal Machining, and Program Sequencing and Output.

McDonnell Douglas, St. Louis, Mo., has released a series of hardware and software enhancements for its Unigraphics system For increased computational capability, the UNIGRAPHICS II software for CAE/CAD/CAM has been repackaged to reside in the DEC VAXstation II/GPX standalone workstation environment. Enhancements to the UNIGRAPHICS II software include utilities for computer-aided engineering, analysis, synthesis, optimization, simulation and documentation and new modules for Machine Elements, Assemblies and Components and Interleaf Interface.

Prime Computer Inc., Natick, Mass., has entered into a series of third-party software agreements to compliment its PRIME MEDUSA



Aries Technology plans to automate concept engineering, which will allow design geometry to be more easily created, verified and modified prior to sending it on to drafting.

software for 2-D CAD, and 3-D modeling. The CADCentre, Cambridge, England provides GNC, an interactive, graphic NC programming system; Merry Mechanization, Wyoming, Minn., provides SMP-81, a sheet-metal design program featuring unfolding routines; from Counting House Computer Systems, Edmunds, England, come the CAMNEST shape-nesting and Q-NEST sheet-metal component programs; and NCNET, a two-way NC-program distribution network is provided by RWT Corporation, Arlington Heights, Ill.

The PROMPT CAD/CAM system from Weber Systems, Inc., Brookfield, Wisc., integrated design, drafting and manufacturing with 2-D or 3-D capabilities. A patented part programming technique simplifies tasks such as spline fitting and point location. In addition to a family of parts, punching and contouring, lathe or milling routines, PROMPT PLUS also includes programming capabilities for 4-axis wire EDM. The software resides in the Hewlett-Packard desktop computer environment.

Solid Modeling

The development of a functional solid modeler has been a long and painstaking task which for many years yielded little more than the ability to create 'pretty pictures'. However, as it became evident that wire frame systems allowed only a limited degree of automated implementation, solid modelers were viewed as the only viable approach to linking CAD and CAM and maximizing the benefits of automated systems.

Early solid modelers (1979), developed at the University of Cambridge, Carnegie-Mellon and the University of Rochester were largely unreliable, non-interactive, anything but user-friendly, required extensive training and EXPENSIVE. But the increased computational capacity and memory technology of today's computer hardware coupled with 'informal' development initiated by users has yielded a practical and productive tool.

Therefore, solid modeling is fast moving out of the academic or manufacturing laborator and into engineering offices. Even with its early limited functionality, the use of solid modelers has doubled yearly since 1979 and is expected to continue to do so through 1990.

The key to solid modeling's inevitable dominance of the CAD/CAM market is the fact that it is the only known way of unambiguously representing the meaning of a design in a computer understandable form.

That means applications such as process plan generation and NC cutter path creation can be totally automated using expert systems to interpret CAD/CAM drawings.

Here's a representative selection of the state-of-the-art in solid modeling.

Swanson Analysis Systems, Inc., Houston, Pa. was founded in 1970 to develop ANSYS, a computer program used to construct models of structures or machine components, apply operating loads and study physical responses such as stress or temperature distribution—all without having to build the object or destroy it in testing.

By using a solid modeler to improve the running logistics of a design, analysis such as statics, dynamics, mode frequency, stability, heat transfer, magnetostatics, and coupled field can be conducted on a wide variety of material representations with ANSYS.

The software is available on mainframes, minicomputers and workstations and ANSYS subsets has been introduced for microcomputers.

Solid modeling R&D conducted by General Electric has been incorporated in Calma's CAD/CAM software for NC tool path verification. In contrast to 3-D wireframe verification systems, Cal-

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ma's solid modeler removes raw material by subtracting the swept volume of each tool motion. The user may then compare the machine-finished part with the original solid-based model. Any discrepancies between the two may indicate machining inaccuracies.

Control Data, Minneapolis, Minn., has developed the ICEM software package for interactive modeling of very complex parts and tasks specific to the plastics, foundry and forging.

In addition to the 2-D/3-D design and drafting program, ICEM offers finite element analysis, group technology and NC programming utilities enhanced by modules specific to electronic, hydraulic or molding applications.

Further, Hewlett-Packard has announced a 3D Modeling system for its Designcenter ME/CAD family. The ME Series 30 as it is called uses a workplane technique to create a three-dimensional model and it expands on the company's previous ME CAD systems which include the ME Series 5, Series 10, and Series 90.

The company noted that its Series 5 and Series 10 which are 2D CAD systems can be upgraded to the new ME Series 30.

The ME 30 Series adapts a 2D concept, the workplane, to locate geometry quickly for creation or modification of 3D models. Users can select any face or cross-section of the model as a workplane, using the screen and tablet menus.

Workplanes are 2D drawing areas in 3D space. A 2D profile can be created on the workplane and "machined" by commands such as MILL, BORE, STAMP or EXTRUDE, producing a 3D model in the process.

Users can designate the workplane by pointing to a face or edge of the displayed model. The workplane can be moved or rotated in a variety of ways.

This workplane design approach simplifies many 3D geometric-construction activities. It facilitates a geometry-creation process that emulates the physical machining that will later produce the real part. The effect is quicker mastery of the system by a new user, and shorter refresher time for occasional designers.

Another system, the HP 9000 Model 320SRX allows rendering of solid objects. The workstation employs a traditional pipeline-graphics architecture. Each of the four stages—display-list traversal, viewing transforms, scan conversion, and image display—is separated by dual-ported memory through which commands and data are passed.

The dual-ported memory approach allows each stage of the pipeline to operate independently, optimizing overall system throughput. This approach also allows for implementation of future enhancements to any stage of the pipeline.

Each stage of the pipeline is memory mapped into the CPU's address space via the local graphics bus (LGB). This memory mapping allows access into any stage of the pipeline in a single memory cycle and provides first-time draw of an object as fast as the redraw (See Fig. 1).

The goal for Model 320RX is high-performance throughput for applications that render shaded solid images. Each stage of the graphics pipeline is optimized for 3-D shaded polygons with hidden-surface removal.

Computer technology has become proficient in optimizing engineering and operations functions. Yet, it has not been used to its potential.

Product development and process control are vital links in the manufacturing scenario. But, the benefits realized from applying computer technology to these stages of manufacturing may yet be improved by an order of magnitude by applying emerging applications software to the factory itself.

As factories become more highly automated it becomes increasingly important to avoid mishaps—collision of robot arms, automated guided vehicle traffic jams or mobile equipment malfunction.

A subset of computer modeling, simulation, is quickly maturing. Such software is becoming easier to program and less costly. By 1990 that market is expected to reach $90 million. P